Indian J. Phys. **71A** (5), 579–583 (1997)

IJP A
— an international journal

Dielectric dispersion studies in cholesteryl propionate

V P Arora* and Anil Kumar
Department of Physics, Vardhaman Post-Graduate College, Bijnor-246 701, Uttar Pradesh, India
and
V K Agarwal
Department of Physics, Ch. C. S University, Meerut-250 004, Uttar Pradesh, India

Received 21 August 1996. accepted 4 March 1997

Abstract : Measurements of dielectric permittivity (ε') and loss (ε'') have been made on cholesteryl propionate in the temperature range of 40–95°C and in the frequency range of 20 KHz–4 MHz both during heating and cooling cycles The results indicate the presence of a dielectric dispersion. However, the values of dielectric parameters during heating run are different than those obtained in the cooling run The results have been used to identify the phase changes that cholesteryl propionate adopts during heating and cooling cycles

Keywords : Cholesteryl propionate, dielectric parameters, phase transition.

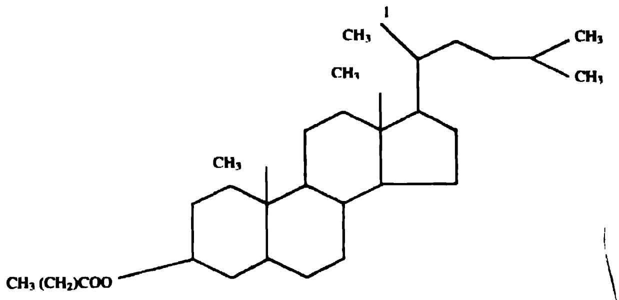
PACS Nos. : 77.22.Ch, 77.22.Gm, 77.84.Nh

1. Introduction

In recent years, liquid crystals have become extremely important because of their rapidly increasing applications in modern technology. Cholesteric liquid crystals find commercial use in both twisted nematic (TN) and guest host (GH) electro-optical displays and also in many thermographic applications [1–3]. Understanding the dielectric behaviour of liquid crystals continues to provide considerable research challenge. There has been only a few studies on the dielectric behaviour of cholesteric liquid crystals [4–9]. This paper reports the results on dielectric measurements on cholesteryl propionate both in heating and cooling cycles and in the frequency range : 20 KHz to 4 MHz. The present study, beside providing knowledge about dielectric dispersion, is expected to identify the phase

* To whom correspondence should be made.

transitions of cholestryl propionate. The cholesteryl propionate ($C_{30}H_{50}O_2$) having the following structure :



and molecular weight : 442.7, was procured from M/s Sigma Chemical Co., U.S.A. and was used as such without any further purification.

2. Experimental

The measurements of dielectric permittivity (ε') and loss (ε'') on cholesteryl propionate were made at 20 KHz, 40 KHz, 100 KHz, 400 KHz, 1 MHz, 2 MHz and 4 MHz using Hewlett Packard L C R meter 4275 A, in the temperature range : 40–95°C.

The sample holder (cell) consisted of two semi circular brass plates (each of diameter : 1.5 cm.) separated by mylar spacer. Two wires, lying on a glass slide and made immovable using araldite adhesive, were attached to these plates.

The cell was placed in a teflon container and covered by a mylar disc. The teflon container, containing cell and mylar, was placed in the sample compartment of the Mettler FP 52 furnace, which was connected to FP 5 control unit. The temperature of the furnace could be precisely measured (accuracy = ±.1°C) by means of a built-in calibrated platinum resistance sensor which is fixed just below the sample slide. The cell was filled with cholesteryl propionate by keeping its temperature more than the isotropic temperature of the material and then the cell was cooled to room temperature. The dielectric measurements were made first for heating run and then for cooling run. Before conducting the measurements, the cell was calibrated using standard substances (benzene, cyclohexane and chlorobenzene) and the effective capacitance C_e of the cell was 4.18 pF-independent of temperature and frequency, in the range of measurements. When the cell was filled with cholesteryl propionate, the values of ε' and ε'' were determined using the relations :

$$\varepsilon' = 1 + \frac{C_m - C_{\text{air}}}{C_e}$$

and

$$\varepsilon'' = \frac{G_m - G_{\text{air}}}{2\pi f \cdot C_e}$$

where C_m and G_m are respectively the values of capacitance and conductance when the sample is inside the cell. C_{air} and G_{air} refer to the same values without any sample, f is the frequency of the measurement. The error in the measurements of ε' was ±1% and that in the measurement of ε'' was ±2%.

3. Results and discussion

Figures 1–4 show the dielectric permittivity components ε' and ε'' at three typical frequencies : 20 KHz, 100 KHz and 2 MHz. It is evident that cholesteryl propionate exhibits

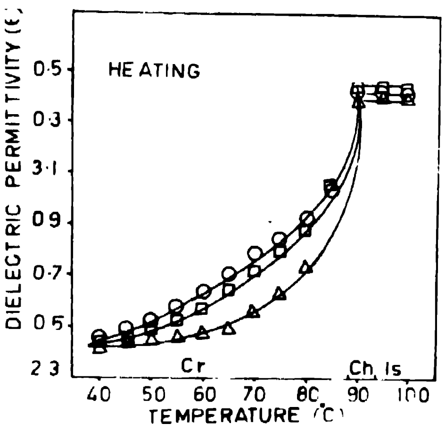


Figure 1. Temperature dependence of dielectric permittivity (ε') at 20 KHz (O), 100 KHz (□) and 2 MHz (Δ) during heating cycle of cholesteryl propionate.

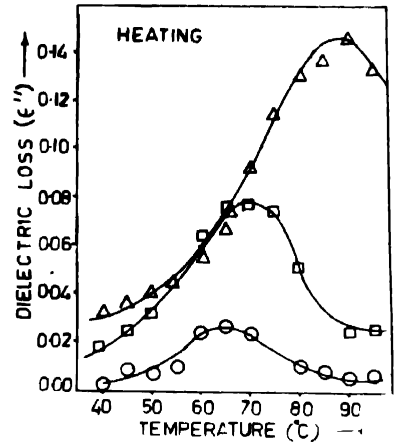


Figure 2. Temperature dependence of dielectric loss (ε'') at 20 KHz (O), 100 KHz (□) and 2 MHz (Δ) during heating cycle of cholesteryl propionate

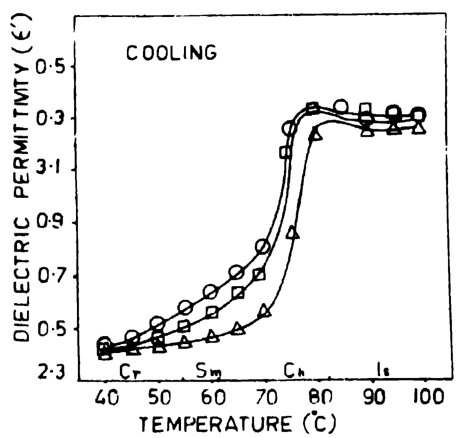


Figure 3. Dielectric permittivity (ε') as a function of temperature at 20 KHz (O), 100 KHz (□) and 2 MHz (Δ) during cooling run of cholesteryl propionate.

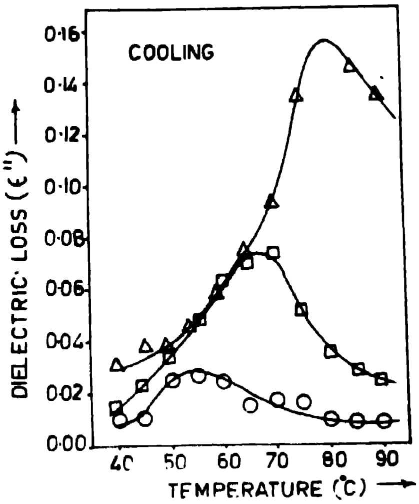


Figure 4. Dielectric loss (ε'') as a function of temperature at 20 KHz (O), 100 KHz (□) and 2 MHz (Δ) during cooling run of cholesteryl propionate.

dielectric dispersion, both during heating and cooling cycles, similar to that observed for other cholesteric liquid crystals [3,4,8–10]. For the demonstration of dielectric properties, the Cole-Cole [11] plots are very instructive. Cole-Cole plots for heating and cooling runs were drawn at different temperatures. The values of low and high frequency limiting permittivities ε_0 and ε_∞ obtained from Cole-Cole plots, are drawn in Figures 5 and 6 both for heating and cooling cycles.

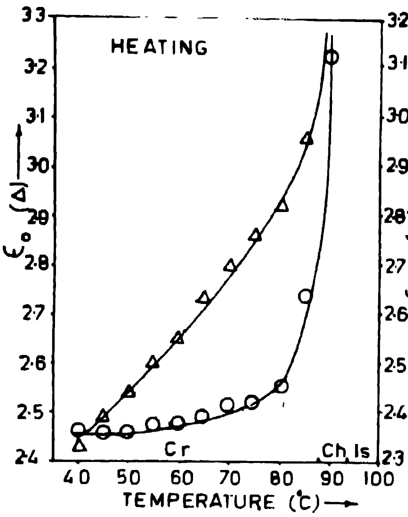


Figure 5. Dependence of low and high frequency limiting permittivities ε_0 and ε_∞ respectively, on temperature during heating run of cholesteryl propionate.

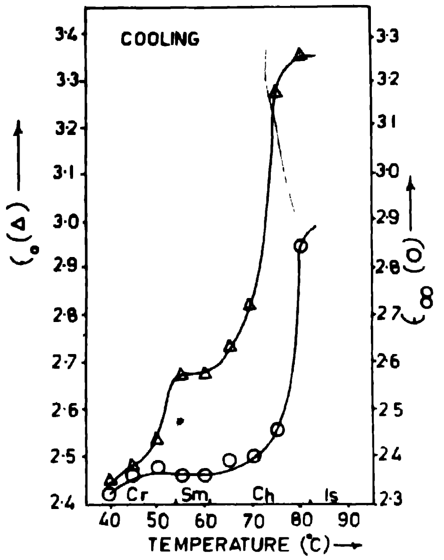


Figure 6. Dependence of low and high frequency limiting permittivities ε_0 and ε_∞ respectively, on temperature during cooling run of cholesteryl propionate.

It seems surprising that at the crystal-to-liquid crystal melting transition, the dielectric permittivity components do not change abruptly. It is the static dielectric permittivity which exhibits the maximum change at the crystal-to-the liquid crystal melting transition. Gouda and coworkers [6,10] have found that in cholesteric liquid crystals, the change in ε' decreases with different thermal cycles and also observed a change in transition temperatures. Further, the change in ε' also decreases with increase in frequency in the region of dielectric dispersion. Recently, it has been preferred to find the transition temperatures from the slope $a\varepsilon'/dT$ [12] which shows discontinuity or peak at the transitions. In the present case, during heating cycle upto 80°C where the sample remains in the crystalline phase, the ε_0 increases linearly, while ε_∞ changes slowly with temperature (Figure 5), so that slopes remain almost constant. With further rise in temperatures, the melting starts, as indicated by the sharp rise in ε_0 and ε_∞ and the material becomes cholesteric at about 89°C. The dielectric permittivity component ε' suddenly takes a large value at about 95°C, indicating that the material has turned into isotropic phase. Similar behaviour identifying the crystalline and cholesteric phases, has been observed earlier [5] in cholesteryl acetate, propionate and stearate. The transition temperature observed in the present case are, however, lower than those reported by Shaw and Kauffman [5]. These transition temperatures, however, resemble closely with 88.6°C and 93.8°C, observed with the Integrated Optical Transmittance studies [13,14] of this mesogen.

While cooling (Figure 3), the cholesteryl propionate continues to remain in the isotropic phase upto about 80°C, after which it acquires cholesteric phase. Similar thermal hysteresis behaviour has been observed in many cholesteric liquid crystals [4–10, 12–14]. The ε_0 and ε_∞ values fall with decrease in temperature upto about 60°C—the cholesteric/smectic phase transition temperature (Figure 6).

In the smectic phase, where the motion of the permanent dipoles is restricted, the ε_0 and ε_∞ values assume constant value upto about 55°C (Figure 6). After 55°C, the smectic-solid phase transition occurs, the limiting permittivity components fall with decrease in temperature and approach to the values obtained during heating cycle. This behaviour of cholesteryl propionate, assuming the isotropic-cholesteric-smectic-crystalline transitions during cooling run, has been confirmed in the Integrated Optical Transmittance studies [13,14] of this mesogen which identified these transitions at 81.9°C, 61°C and 54.1°C respectively.

Acknowledgments

We are grateful to the Chairman, Department of Physics, Garyounis University, Benghazi, Libya for providing the necessary facilities.

References

[1] D L White and G N Taylor *J. Appl. Phys.* **45** 4718 (1974)

[2] A Goble, A Wiensch, G Heppke and F Oestericher *J. Phys.* (Paris) **40** 773 (1979)

[3] B Bahadur (ed.) *Liquid Crystals : Applications and Uses* Vol I II and III (Singapore . World Scientific) (1994)

[4] H Baessler, R B Beard and M M Labes *J. Chem. Phys.* **52** 2292 (1970)

[5] D G Shaw and J W Kauffman *Phys. Stat. Sol (a)* **12** 637 (1972)

[6] F M Gouda, S K Suri and S L Srivastava *Proc. Nat. Acad. Sci.* (India) **61A** 103 (1991)

[7] S L Srivastava and D C Dwivedi *Proc. Nat Sci.* (India) **60A** 11 235 (1990)

[8] V K Agarwal, J P Shukla, V P Arora and S M Elamen *Nat. Acad. Sci. Lett.* **13** 12 453 (1990)

[9] F Gouda *Liquid Crystals* **17** 367 (1994)

[10] S L Srivastava, S K Suri and F M Gouda *Nat. Acad. Sci. Lett.* **6** 11 351 (1983)

[11] K S Cole and R H Cole *J. Chem. Phys.* **9** 341 (1949)

[12] Ravindra Dhar *DPhil Thesis* (University of Allahabad, India) (1996)

[13] V P Arora, V K Agarwal and S F Auda *61st Annual Session of Nat. Acad. of Sciences* (India) Abst. No 95 (1991)

[14] V P Arora, Anil Kumar, V K Agarwal and S F Auda *Asian J. Phys.* **6** 3, 101 (1997)